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(54) **FINGERPRINT SENSOR PACKAGE AND METHOD**

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(51) **Int. Cl.**
H05K 1/11 (2006.01)

(52) **U.S. Cl.**
USPC **361/803**; 361/761

(58) **Field of Classification Search**
USPC 361/803, 56, 112, 220, 230, 719, 720, 361/761, 764, 767, 768, 780; 174/255
See application file for complete search history.

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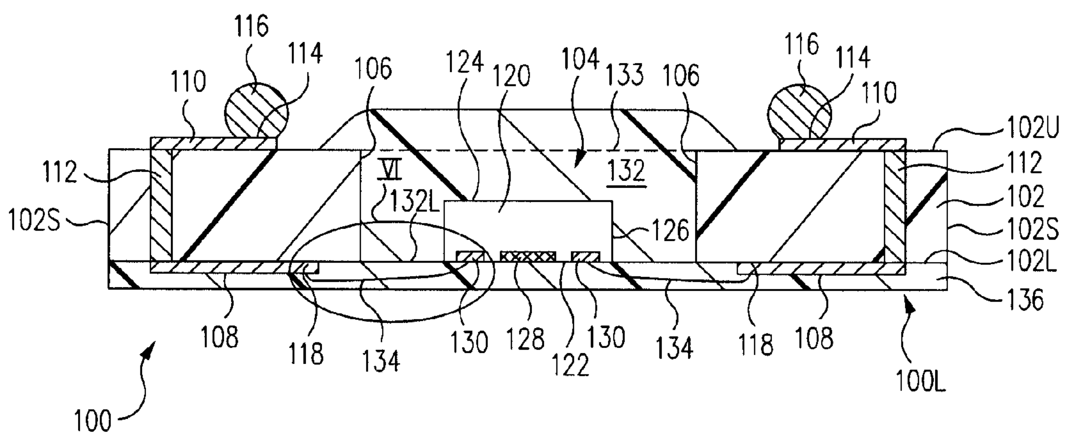
(57) **ABSTRACT**

A fingerprint sensor package includes a flat surface having a dielectric protective coating protecting a sensing element of a fingerprint sensor and an electrically conductive bezel that discharges electrostatic discharge (ESD). Both the protective coating and the bezel can be colored to have desired colors. Accordingly, the flat surface can be colored as desired enhancing the attractiveness for consumer applications. Further, light emitting diodes are integrated into the fingerprint sensor package providing a visual feedback to the user that the user's fingerprint has been successfully sensed. Further, the fingerprint sensor package is formed using a high volume low cost assembly technique.

18 Claims, 7 Drawing Sheets



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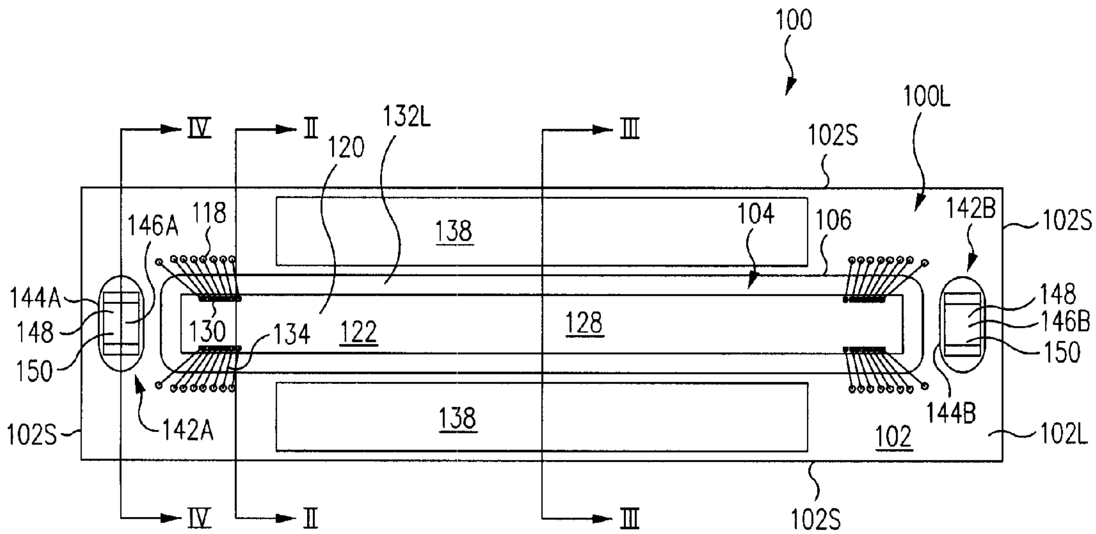
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FIG. 1

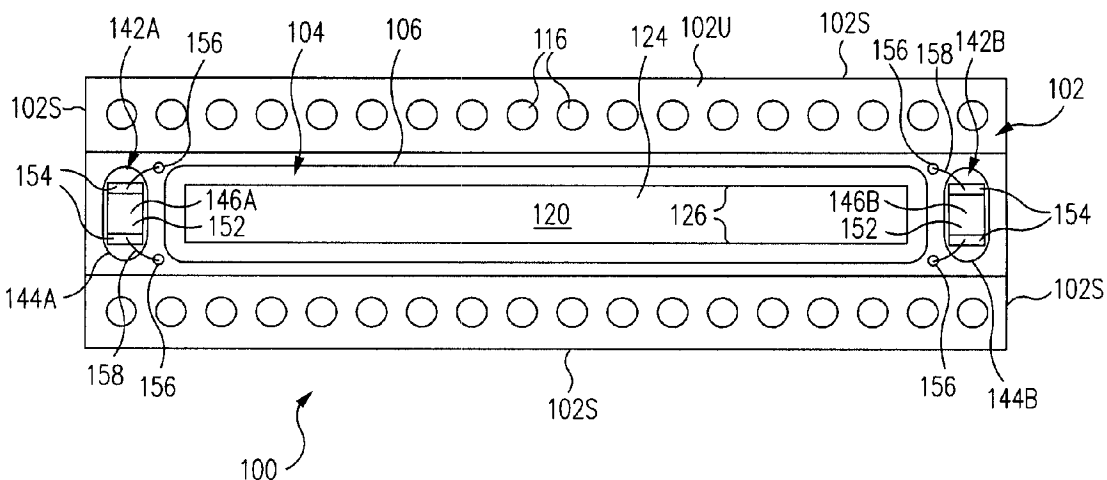
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FIG. 5

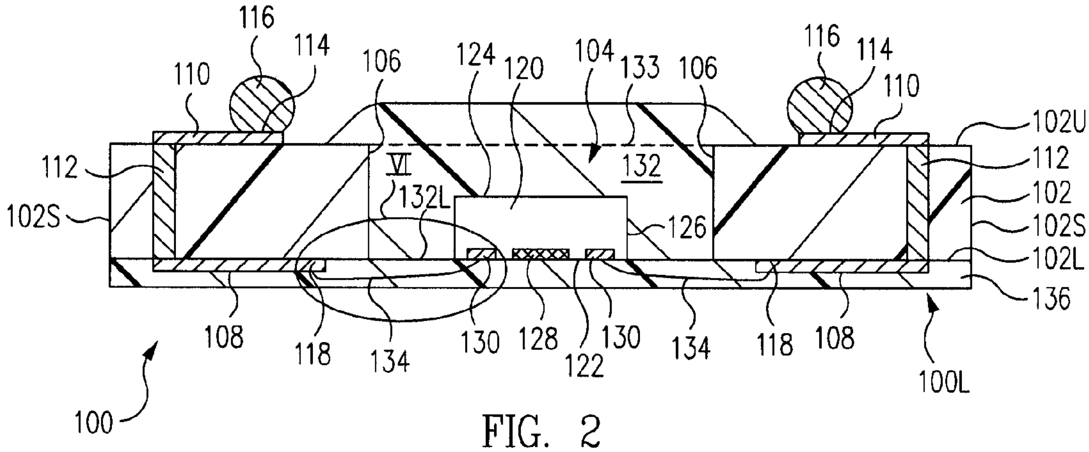

FIG. 2

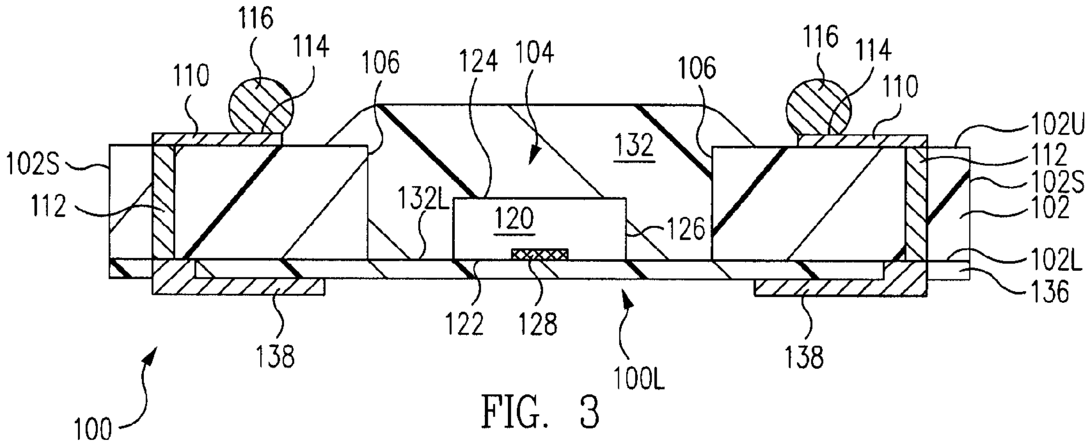

FIG. 3

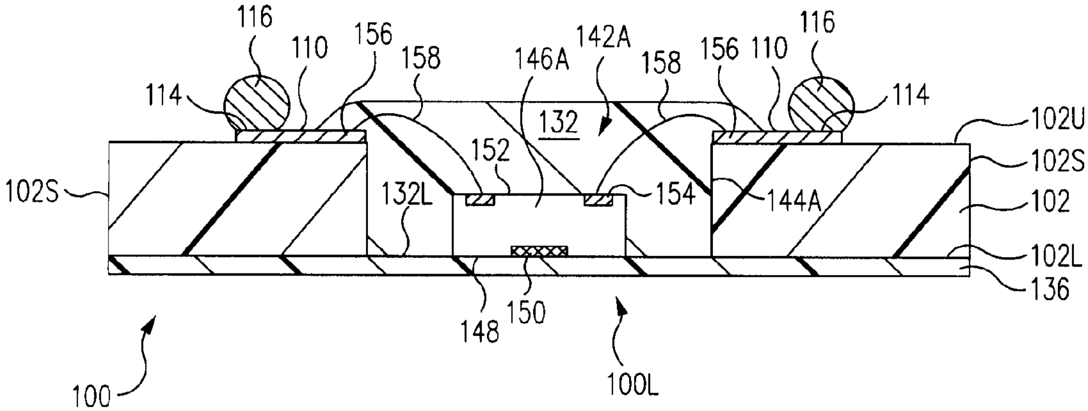

FIG. 4

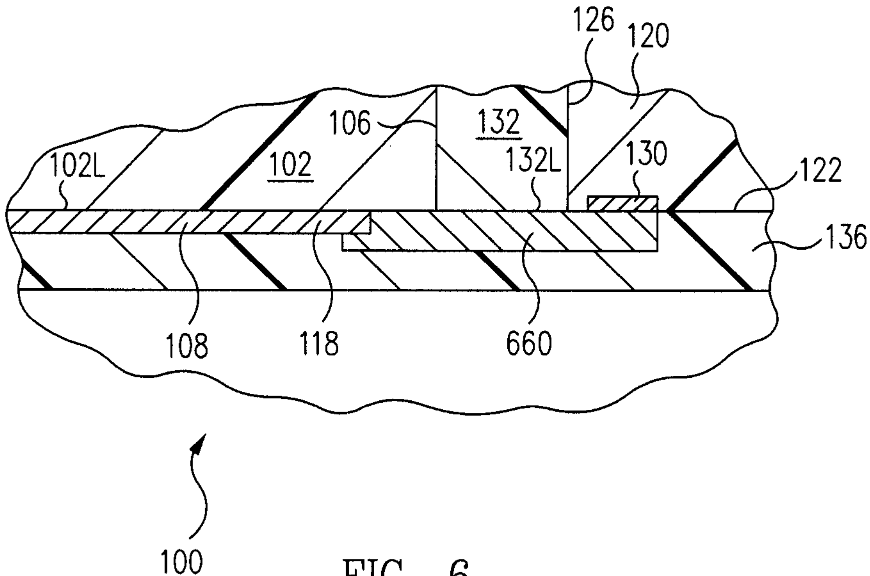

FIG. 6

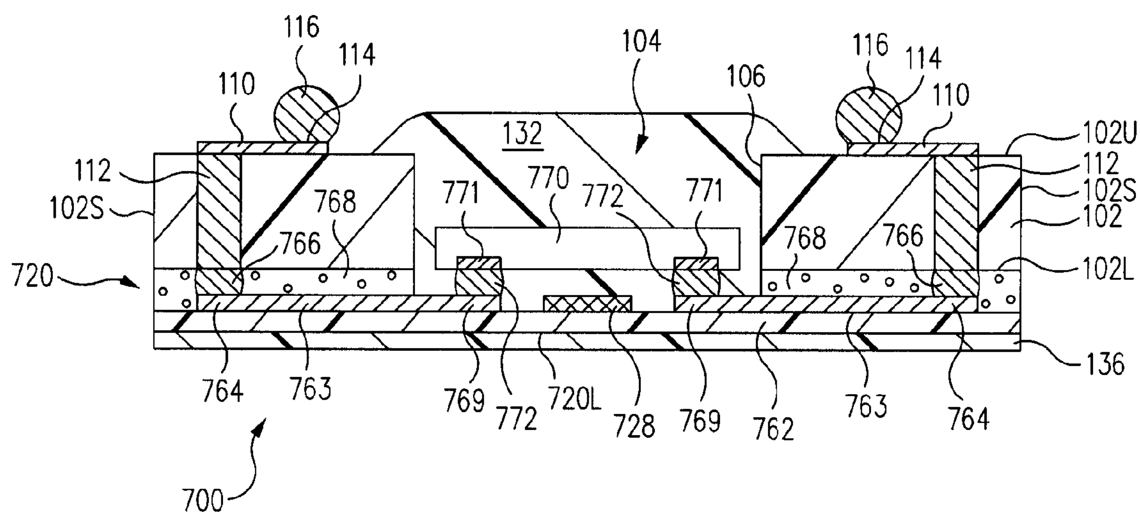
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FIG. 7

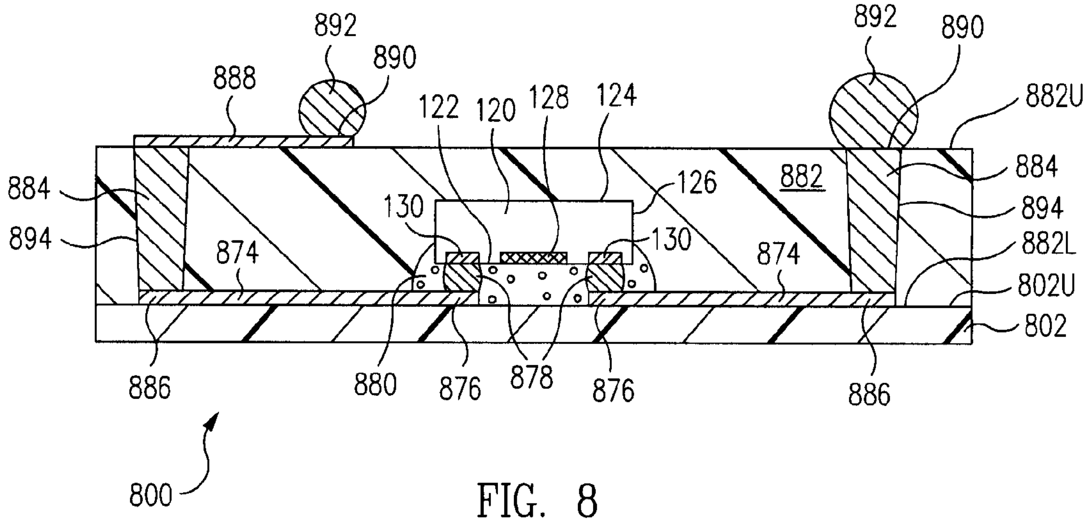
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FIG. 8

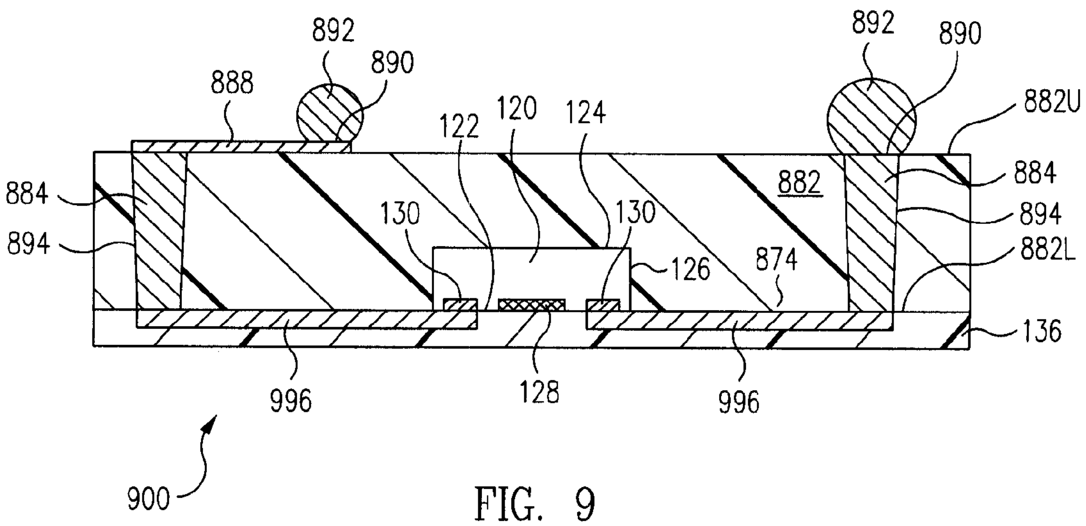
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FIG. 9

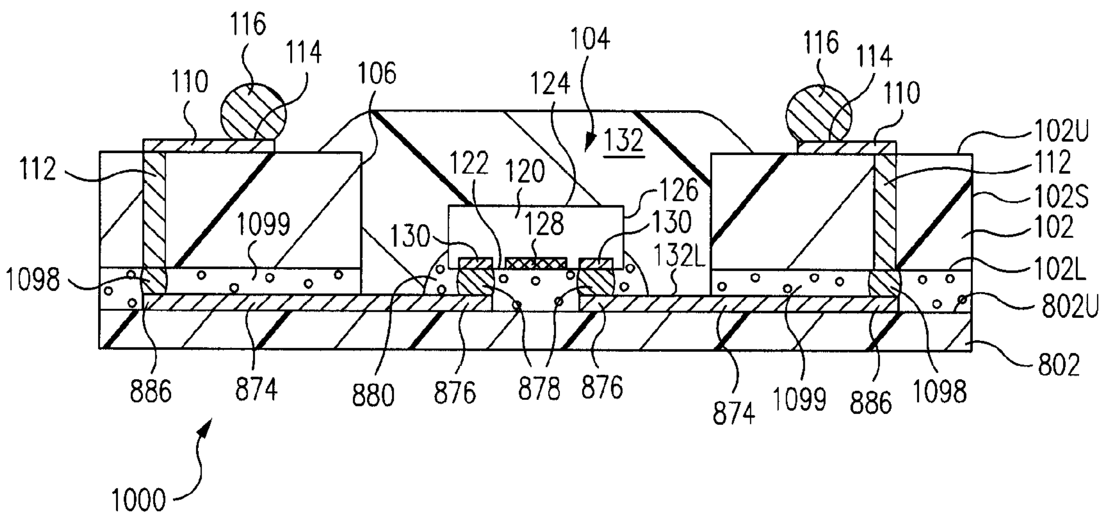
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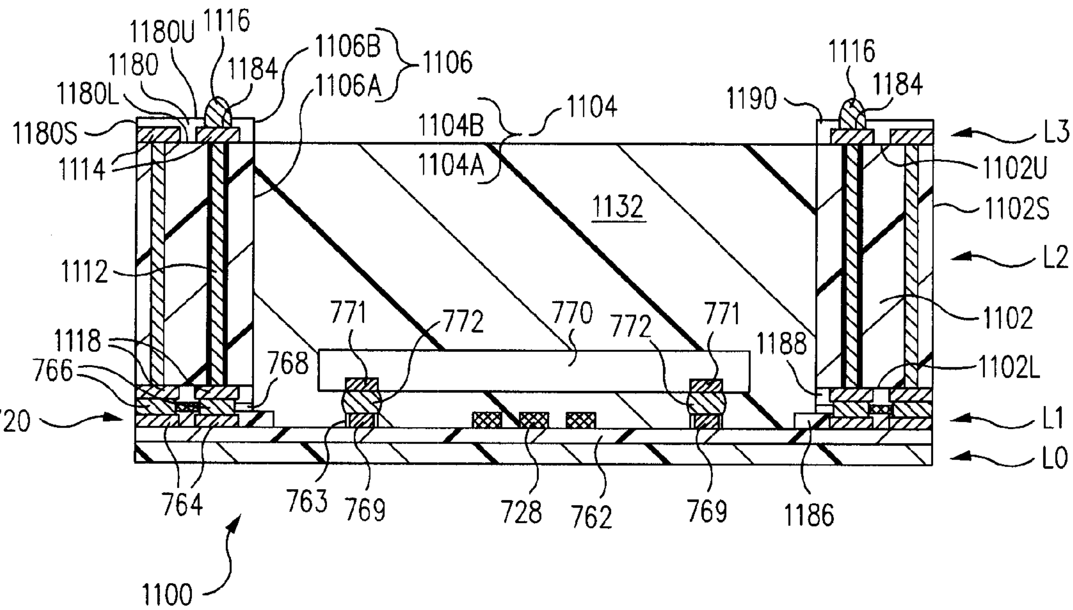
FIG. 10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762
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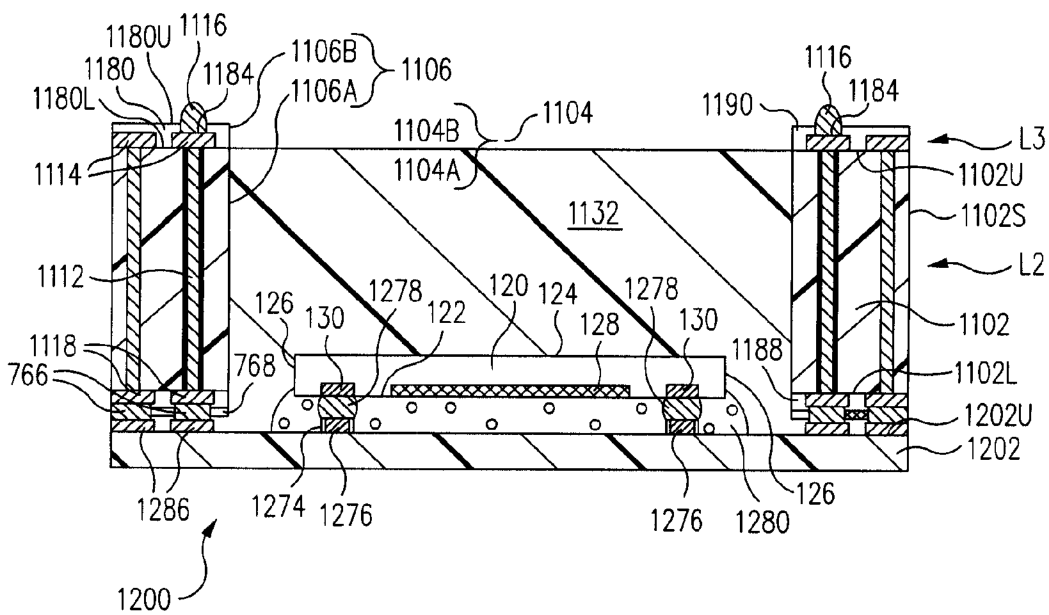
L1
L0

FIG. 11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1274
1276
1276
1280
126
1200
1116
1184
1190
L3
1102U
1102S
L2
1102
1102L
1202U
1202

FIG. 12

FINGERPRINT SENSOR PACKAGE AND METHOD

TECHNICAL FIELD

The present application relates to the field of electronics, and more particularly, to methods of forming electronic component packages and related structures.

BACKGROUND

For user verification and other purposes, many devices such as portable computers and cellular telephone include a fingerprint sensor. A fingerprint sensor, sometimes called a biometric sensor, senses a fingerprint of a finger place on the fingerprint sensor. The obtained fingerprint is compared to an authorized user's stored fingerprint. If there is a match, the user is verified.

There are two commonly used fingerprint sensors in consumer applications. The first type of fingerprint sensor is a silicon die fingerprint sensor. The sensing element that senses the fingerprint is located on an active surface of the silicon die fingerprint sensor.

The second type of fingerprint sensor is a sensing element on flex fingerprint sensor. The sensing element that senses the fingerprint is located on a flexible dielectric substrate.

To reduce the cost of the devices in which the fingerprint sensors are used, it is desirable to package the fingerprint sensors at low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a bottom plan view of a full cavity fingerprint sensor package in accordance with one embodiment;

FIGS. **2**, **3**, **4** are cross-sectional views of the full cavity fingerprint sensor package of FIG. **1** along lines II-II, III-III, IV-IV, respectively, in accordance with various embodiments;

FIG. **5** is a top plan view of the full cavity fingerprint sensor package of FIG. **1** in accordance with one embodiment;

FIG. **6** is an enlarged cross-sectional view of the region VI of the full cavity fingerprint sensor package of FIG. **2** in accordance with another embodiment;

FIG. **7** is a cross-sectional view of a full cavity fingerprint sensor package in accordance with another embodiment;

FIG. **8** is a cross-sectional view of a thin substrate fingerprint sensor package in accordance with another embodiment;

FIG. **9** is a cross-sectional view of a fingerprint sensor package in accordance with another embodiment;

FIG. **10** is a cross-sectional view of a hybrid fingerprint sensor package in accordance with another embodiment;

FIG. **11** is a cross-sectional view of a fingerprint sensor package in accordance with another embodiment; and

FIG. **12** is a cross-sectional view of a fingerprint sensor package in accordance with yet another embodiment.

In the following description, the same or similar elements are labeled with the same or similar reference numbers.

DETAILED DESCRIPTION

As an overview and in accordance with one embodiment, referring to FIGS. **1-5**, a fingerprint sensor package **100** includes a flat surface **100**L having a dielectric protective coating **136** protecting a sensing element **128** of a fingerprint sensor **120** and an electrically conductive bezel **138** that discharges electrostatic discharge (ESD). Both protective coating **136** and bezel **138** can be colored to have desired colors.

Accordingly, flat surface **100**L can be colored as desired enhancing the attractiveness for consumer applications. Further, light emitting diodes **146**A, **146**B are integrated into fingerprint sensor package **100** providing a visual feedback to the user that the user's fingerprint has been successfully sensed. Further, fingerprint sensor package **100** is formed using a high volume low cost assembly technique.

Now in more detail, FIG. **1** is a bottom plan view of a full cavity fingerprint sensor package **100** in accordance with one embodiment. FIGS. **2**, **3**, **4** are cross-sectional views of full cavity fingerprint sensor package **100** of FIG. **1** along lines II-II, III-III, IV-IV, respectively, in accordance with various embodiments. FIG. **5** is a top plan view of full cavity fingerprint sensor package **100** of FIG. **1** in accordance with one embodiment. Although FIGS. **1**, **5** are referred to as bottom and top plan views, respectively, full cavity fingerprint sensor package **100** can be used in any orientation without respect to gravity. Accordingly, FIGS. **1** and **5** are sometimes called the finger side plan view and the interconnect side plan view, respectively.

Full cavity fingerprint sensor package **100**, sometimes called an electronic component package, includes a substrate **102** having a lower, e.g., first, surface **102**L and an upper, e.g., second surface **102**U. Substrate **102** further includes a fingerprint sensor cavity **104** formed therein. Fingerprint sensor cavity **104**, sometimes called a hole or aperture, extends entirely through substrate **102** and between upper surface **102**U and lower surface **102**L.

Fingerprint sensor cavity **104** is defined by a fingerprint sensor cavity sidewall **106**. Fingerprint sensor cavity sidewall **106** extends perpendicularly between upper surface **102**U and lower surface **102**L. Although the terms parallel, perpendicular, coplanar and similar terms are used herein, it is to be understood that the described features may not be exactly parallel, perpendicular, and coplanar, but only substantially parallel, perpendicular, and coplanar to within excepted manufacturing tolerances.

Substrate **102** further includes outer sides **102**S extends perpendicularly between upper surface **102**U and lower surface **102**L. Substrate **102** includes a dielectric material such as laminate, ceramic, printed circuit board material, or other dielectric material. In one particular embodiment, substrate **102** is a cavity laminate substrate.

Substrate **102** further includes lower, e.g., first, traces **108** formed at lower surface **102**L and upper, e.g., second, traces **110** formed at upper surface **102**U. Lower traces **108** are electrically connected to upper traces **110** by electrically conductive vias **112** extending through substrate **102** between upper surface **102**U and lower surface **102**L.

Upper traces **110** include terminals **114** upon which interconnection balls **116**, e.g., solder balls, are formed. Although not illustrated in the figures, substrate **102** can further include an upper solder mask on upper surface **102**U that protects upper traces **110** while exposing terminals **114**. In one embodiment, interconnection balls **116** are distributed in an array thus forming a Ball Grid Array (BGA).

Lower traces **108** also include terminals **118**, sometimes called bond fingers. Although not illustrated in the figures, substrate **102** can further include a lower solder mask on lower surface **102**L that protects lower traces **108** while exposing terminals **118**.

Although a particular electrically conductive pathway is described above, other electrically conductive pathways can be formed. For example, contact metallizations can be formed between the various electrical conductors.

Further, instead of straight though vias **112**, in one embodiment, substrate **102** is a multilayer substrate and a plurality of vias and/or internal traces form the electrical interconnection between upper traces **110** and lower traces **108**. Further, instead of a BGA, full cavity fingerprint sensor package **100** can be formed as a Land Grid Array (LGA) or other style package.

Paying particular attention now to FIGS. **1** and **2** together, full cavity fingerprint sensor **100** further includes a silicon die fingerprint sensor **120**. Silicon die fingerprint sensors are well known to those of skill in the art, accordingly, only a brief description of silicon die fingerprint sensor **120** is provided below.

Silicon die fingerprint sensor **120** includes an active surface **122**, an opposite inactive surface **124**, and sides **126** extending perpendicularly between active surface **122** and inactive surface **124**.

Silicon die fingerprint sensor **120** further includes a sensing element **128** and bond pads **130** on active surface **122**. Sensing element **128**, e.g., fine pitch metal patterns, senses fingerprints placed upon (or near) silicon die fingerprint sensor **120**. Bond pads **130** are electrically connected to the internal circuitry of silicon die fingerprint sensor **120**.

Silicon die fingerprint sensor **120** is mounted within fingerprint sensor cavity **104** of substrate **102**. More particularly, active surface **122** is parallel to and coplanar with lower surface **102**L of substrate **102**.

In one embodiment, a removable tape is applied to lower surface **102**L of substrate **102** and seals fingerprint sensor cavity **104** at lower surface **102**L. Silicon die fingerprint sensor **120** is placed, active surface **122** down, upon the removable tape.

A package body **132**, e.g., mold compound, epoxy or other reliable material, is formed around silicon die fingerprint sensor **120** and fills fingerprint sensor cavity **104**. More particularly, package body **132** encapsulates, sometimes called encloses, covers or encases, inactive surface **124** and sides **126** of silicon die fingerprint sensor **120**.

Further, package body **132** encapsulates fingerprint sensor cavity sidewall **106** and a portion of upper surface **102**U of substrate **102** adjacent fingerprint sensor cavity **104**. In another embodiment, package body **132** fills, partially or completely, fingerprint sensor cavity **104** but does not extend upon upper surface **102**U of substrate **102**.

For example, package body **132** is flush with upper surface **102**U of substrate **102** as indicated by the dashed line **133** in FIG. **2** which supports formation of a LGA on upper surface **102**U. For example, terminals **114** form lands for the LGA although terminals **114** are coupled to other electrically conductive structures which form lands for the LGA in other examples.

In either example, package body **132** is not illustrated in FIG. **5** to allow visualization of features within package body **132**.

After formation of package body **132**, silicon die fingerprint sensor **120** is secured and mounted within fingerprint sensor cavity **104** by package body **132**. Accordingly, the removable tape is removed thus exposing active surface **122** including sensing element **128** and bond pads **130**. Thus, active surface **122**, lower surface **102**L of substrate **102**, and a lower, e.g., first, surface **132**L of package body **132** are parallel to and coplanar with one another.

Bond pads **130** are electrically connected to terminals **118** of lower traces **108** by bond wires **134**. In one embodiment, bond wires **134** are low loop thin wire bonds to minimize the loop height of bond wires **134**, e.g., are zero loop height.

A protective coating **136** is applied to cover the lower surface **100**L of full cavity fingerprint sensor **100**. More particularly, protective coating **136**, e.g., a dielectric protective epoxy or nonconductive ink, is applied to cover active surface **122** including sensing element **128** and bond pads **130** of silicon die fingerprint sensor **120**. Further, protective coating **136** is applied to lower surface **132**L of package body **132**. Further, protective coating **136** is applied to cover lower surface **102**L of substrate **102** including lower traces **118**. In addition, protective coating **136** is applied to cover bond wires **134**.

Protective coating **136** protects active surface **122**, sensing element **128**, bond pads **130**, lower surface **132**L of package body **132**, lower surface **102**L of substrate **102**, lower traces **118**, and bond wires **134** from the ambient environment. Accordingly, full cavity fingerprint sensor package **100** is robust, i.e., resistant to external damage.

In one embodiment, protective coating **136** is colored to have a desired color. Protective coating **136** is not illustrated in FIG. **1** to allow visualizations of features below protective coating **136**.

Paying particular attention now to FIGS. **1** and **3** together, full cavity fingerprint sensor package **100** further includes an electrically conductive bezel **138**. In accordance with the illustrated embodiment, bezel **138** is formed on protective coating **136** adjacent silicon die fingerprint sensor **120**. In another embodiment, bezel **138** is formed on lower surface **102**L of substrate **102** and protective coating **136** is patterned around bezel **138** to expose bezel **138**.

In one embodiment, bezel **138** includes a metal plane and can further include an electrically conductive ink. In another embodiment, bezel **138** is formed of electrically conductive ink, e.g., applied directly over blind ground vias, and does not include a metal plane. In either case, bezel **138** can be colored as desired by selecting an appropriately colored conductive ink.

Bezel **138** is electrically connected to vias **112**. During use, the respective interconnection balls **116** are electrically connected to a reference voltage source, e.g., ground. Accordingly, bezel **138** is electrically connected to the reference voltage source, e.g., ground. Thus, bezel **138** discharges electrostatic discharge (ESD) from a finger contacting full cavity fingerprint sensor package **100**.

Paying particular attention now to FIGS. **1**, **4** and **5** together, substrate **102** further includes light emitting diode (LED) cavities **142**A, **142**B. LED cavities **142**A, **142**B, sometimes called holes or apertures, extend entirely through substrate **102** and between upper surface **102**U and lower surface **102**L. Although separate fingerprint sensor cavity **104** and LED cavities **142**A, **142**E are set forth, in another embodiment, fingerprint sensor cavity **104** and LED cavities **142**A, **142**B are integrated into a single cavity.

LED cavities **142**A, **142**B are defined by LED cavity sidewalls **144**A, **144**B, respectively. LED cavity sidewalls **144**A, **144**B extend perpendicularly between upper surface **102**U and lower surface **102**L.

Full cavity fingerprint sensor package **100** includes a first light emitting diode **146**A and a second light emitting diode **146**A mounted within LED cavities **142**A, **142**B, respectively.

Paying particular attention to first light emitting diode **146**A, light emitting diode **146**A includes a light emitting face **148** including a light emitting area **150**. Light emitting diode **146**A further includes an inactive surface **152** having bond pads **154** formed thereon.

Bond pads **154** are electrically connected to upper traces **110**, e.g., bond fingers **156** thereof, by electrically conductive bond wires **158**. During use, light emitting area **150** emits light based on signals on bond pads **154** as those of skill in the art will understand in light of this disclosure. For example, light is emitted to provide a visual feedback to the user that the user's fingerprint has been successfully sensed.

Light emitting diode **146**B is similar or identical to light emitting diode **146**A and thus the discussion of light emitting diode **146**A including mounting and electrical interconnection therewith is equally applicable to light emitting diode **146**B and so is not repeated.

In one embodiment, a removable tape, e.g., the same removable tape used to mount silicon die fingerprint sensor **120** as discussed above, is applied to lower surface **102**L of substrate **102**. The removal tape seals LED cavities **142**A, **142**B at lower surface **102**L. Light emitting diodes **146**A, **146**B are placed, light emitting faces **148** down, upon the removable tape.

Package body **132**, e.g., the same mold compound used to encapsulate silicon die fingerprint sensor **120**, is formed around light emitting diodes **146**A, **146**B and fills LED cavities **142**A, **142**B, respectively.

Package body **132** encapsulates, sometimes called encloses, covers, or encases, inactive surfaces **152** and sides of light emitting diodes **146**A, **146**B. Further, package body **132** encapsulates LED cavity sidewalls **144**A, **144**B and, optionally, portions of upper surface **102**U of substrate **102** adjacent LED cavities **142**A, **142**B. In accordance with this embodiment, package body **132** further encapsulates bond wires **158** and bond fingers **156** of upper traces **110**.

After formation of package body **132**, light emitting diodes **146**A, **146**B are secured within LED cavities **142**A, **142**B by package body **132**. Accordingly, the removable tape is removed thus exposing light emitting faces **148** including light emitting areas **150**. Thus, light emitting faces **148**, lower surface **102**L of substrate **102**, and lower surface **132**L of package body **132** are parallel to and coplanar with one another.

Protective coating **136** is applied to cover and protect light emitting faces **148** including light emitting areas **150** of light emitting diodes **146**A, **146**B.

In accordance with yet another embodiment, bond pads **154** are formed on light emitting faces **148** of light emitting diodes **146**A, **146**B instead of on inactive surfaces **152** as illustrated. In accordance with this embodiment, bond pads **154** on light emitting faces **148** are electrically connected to terminals **118** of lower traces **108** by bond wires **134** in a manner similar to that illustrated in FIG. **2** and discussed above.

In accordance with one embodiment, referring now to FIGS. **1**, **2**, **3**, **4** and **5** together, a method of fabricating full cavity fingerprint sensor package **100** includes providing substrate **102** having fingerprint sensor cavity **104** and LED cavities **142**A, **142**B formed therein. A removable tape is applied to lower surface **102**L of substrate **102** and seals fingerprint sensor cavity **104** and LED cavities **142**A, **142**B.

Silicon die fingerprint sensor **120** and light emitting diodes **146**A, **146**B are mounted to the removable tape and within fingerprint sensor cavity **104** and LED cavities **142**A, **142**B, respectively. Bond pads **154** of light emitting diodes **146**A, **146**B are electrically connected to bond fingers **156** of upper traces **110** with bond wires **158**. Silicon die fingerprint sensor **120** and light emitting diodes **146**A, **146**B are encapsulated within package body **132**. The removable tape is removed. Bond pads **130** of silicon die fingerprint sensor **120** are electrically connected to terminals **118** of lower traces **108** by bond wires **134**. Protective coating **136** and bezel **138** are formed.

In one embodiment, full cavity fingerprint sensor package **100** is formed simultaneously with a plurality of full cavity fingerprint sensor packages **100** in an array or strip as described above. The array or strip is cut to singulate the full cavity fingerprint sensor package **100** from one another. By forming full cavity fingerprint sensor package **100** in an array or strip, a high volume low cost assembly technique is achieved.

Full cavity fingerprint sensor package **100** provides a flat lower surface **100**L. As set forth above, both protective coating **136** and bezel **138** can be colored to have desired colors. Accordingly, lower surface **100**L can be colored as desired enhancing the attractiveness for consumer applications. Further, light emitting diodes **146**A, **146**B and bezel **138** are integrated into full cavity fingerprint sensor package **100**. Further, full cavity fingerprint sensor package **100** is formed using a high volume low cost assembly technique in one embodiment.

FIG. **6** is an enlarged cross-sectional view of the region VI of full cavity fingerprint sensor package **100** of FIG. **2** in accordance with another embodiment. In accordance with this embodiment, instead of using bond wires, bond pads **130** are electrically connected to terminals **118** of lower traces **108** by electrically conductive polymer thick film (PTF) conductors **660**. Illustratively, PTF conductors **660** are formed by screen printing electrically conductive polymer thick film. Although not illustrated in FIG. **6**, in one embodiment, one or more dielectric layers are applied prior to formation of PTF conductors **660** and patterned to expose bond pads **130** and terminals **118**. Further, protective coating **136** covers and protects PTF conductors **660**.

FIG. **7** is a cross-sectional view of a full cavity fingerprint sensor package **700** in accordance with another embodiment. Full cavity fingerprint sensor package **700** of FIG. **7** is similar to full cavity fingerprint sensor package **100** of FIGS. **1**-**5** with one notable exception being that full cavity fingerprint sensor package **700** is formed with a sensing element on flex fingerprint sensor **720**.

More particularly, full cavity fingerprint sensor package **700** includes substrate **102**, lower surface **102**L, upper surface **102**U, sides **102**S, fingerprint sensor cavity **104**, fingerprint sensor cavity sidewall **106**, upper traces **110**, vias **112**, terminals **114**, interconnection balls **116**, package body **132**, and protective coating **136** similar or identical to substrate **102**, lower surface **102**L, upper surface **102**U, sides **102**S, fingerprint sensor cavity **104**, fingerprint sensor cavity sidewall **106**, upper traces **110**, vias **112**, terminals **114**, interconnection balls **116**, package body **132**, and protective coating **136** of full cavity fingerprint sensor package **100** of FIG. **1**, respectively, and so the description thereof is not repeated here.

Referring now to FIG. **7**, sensing element on flex fingerprint sensor **720** includes a flexible substrate **762**, a sensing element **728** and traces **763**. Flexible substrate **762** is a flexible dielectric substrate. Sensing element **728**, e.g., fine pitch metal patterns, is formed on flexible substrate **762**. Sensing element **728** senses fingerprints placed upon flexible substrate **762** directly opposite sensing element **728**.

Traces **763** are formed on flexible substrate **762**. Traces **763** include substrate terminals **764**. Substrate terminals **764** are electrically connected to vias **112** at lower surface **102**L of substrate **102** with electrically conductive substrate bumps **766**. In one embodiment, an adhesive **768** fills the region between lower surface **102**L of substrate **102** and sensing element on flex finger sensor **720**.

Traces **763** further include electronic component terminals **769**. An electronic component **770** is flip chip mounted, i.e., bond pads **771** thereof, to electronic component terminals **769** with flip chip bumps **772**. Electronic component **770** is an application specific integrated circuit (ASIC) that controls the operation of sensing element **728** as those of skill in the art will understand in light of this disclosure. Protective coating **136** covers the lower exposed surface **720**L of sensing element on flex finger sensor **720**. Although electronic component **770** is illustrated and described as being mounted in a flip chip configuration, in another embodiment, electronic component **770** is mounted in a wirebond configuration wherein bond pads **771** are electrically connected to electronic component terminals **769** with bond wires.

A package body **132**, e.g., mold compound, is formed around electronic component **770** and the exposed portion of sensing element on flex fingerprint sensor **720**. More particularly, package body **132** fills fingerprint sensor cavity **104**.

FIG. **8** is a cross-sectional view of a thin substrate fingerprint sensor package **800** in accordance with another embodiment. In accordance with this embodiment, thin substrate fingerprint sensor package **800** includes a dielectric thin substrate **802**. Formed on an upper, e.g., first, surface **802**U of thin substrate **802** are electrically conductive traces **874**.

Bond pads **130** of silicon die fingerprint sensor **120** are physically and electrically connected to electronic component terminals **876** of traces **874** by electrically conductive flip chip bumps **878**, i.e., silicon die fingerprint sensor **120** is flip chip mounted to traces **874**. Flip chip bumps **878** are low standoff bumps in one embodiment to minimize the distance between a finger and sensing element **128**. Optionally, an underfill **880** is applied between active surface **122** of silicon die fingerprint sensor **120** and upper surface **802**U of thin substrate **802** and to enclose flip chip bumps **878**.

To reduce the distance between a finger touching thin substrate **802** and sensing element **128**, in one embodiment, thin substrate **802** is thinned.

A package body **882**, e.g., molding compound, encloses inactive surface **124** and sides **126** of silicon die fingerprint sensor **120**, underfill **880**, upper surface **802**U of thin substrate **802**, and any expose portions of traces **874**.

Package body **882** includes an upper, e.g., first, surface **882**U and opposite lower, e.g., second, surface **882**L. Electrically conductive vias **884**, sometimes called through mold vias (TMV), extend through package body **882** from upper surface **882**U to lower surface **882**L. Vias **884** are electrically connected to substrate terminals **886** of traces **874**.

As illustrated at the left side of thin substrate fingerprint sensor package **800** of FIG. **8**, optionally, upper traces **888** are electrically connected to vias **884**. Upper traces **888** are formed on upper surface **882**U of package body **884**, although are embedded within upper surface **882**U in other embodiments. Upper traces **888** include terminals **890**. Interconnection balls **892** are formed on terminals **890**.

In yet another embodiment, as illustrated at the right side of thin substrate fingerprint sensor package **800** of FIG. **8**, the upper surfaces of vias **884** form terminals **890**.

In one embodiment, to form fingerprint sensor package **800**, silicon die fingerprint sensor **120** is flip chip mounted to terminals **876** by flip chip bumps **878**. Underfill **880** is applied between active surface **122** of silicon die fingerprint sensor **120** and upper surface **802**U of thin substrate **802**.

The assembly is over molded to form package body **882**. Via apertures **894** are formed through package body **882**, e.g., using laser ablation, to expose substrate terminals **886** of traces **874**. Via apertures **894** are filled, fully or partially, with electrically conductive material, e.g., copper, to form vias **884**. Optionally, upper traces **888** are formed and interconnection balls **892** are formed on terminals **890**.

Referring now to FIGS. **7** and **8** together, in another embodiment, thin substrate fingerprint sensor package **800** is formed with sensing element on flex fingerprint sensor **720** instead of silicon die fingerprint sensor **120**. In accordance with this embodiment, sensing element on flex fingerprint sensor **720** is mounted to thin substrate **802**. The assembly is over molded to form package body **882**. Via apertures **894** are formed through package body **882**, e.g., using laser ablation, to expose substrate terminals **764** of traces **763**. Via apertures **894** are filled, fully or partially, with electrically conductive material, e.g., copper, to form vias **884**. Optionally, upper traces **888** are formed and interconnection balls **892** are formed on terminals **890**.

FIG. **9** is a cross-sectional view of a fingerprint sensor package **900** in accordance with another embodiment. Fingerprint sensor package **900** of FIG. **9** is similar to fingerprint sensor package **800** of FIG. **8** and only the significant differences are discussed below.

Referring now to FIG. **9**, in accordance with this embodiment, bond pads **130** of silicon die fingerprint sensor **120** are electrically connected to vias **884** by traces **996**, sometimes called redistribution layer (RDL) traces. Traces **996** are formed on lower surface **882**L of package body **882** although in one embodiment a dielectric layer is applied between lower surface **882**L and traces **996**. Traces **996**, lower surface **882**L of package body **882** and active surface **122** of silicon die fingerprint sensor **120** are enclosed in protective coating **136**.

In one embodiment, to form fingerprint sensor package **900**, silicon die fingerprint sensor **120** is mounted, active surface **122** down, on a removable carrier. Silicon die fingerprint sensor **120** is encapsulated within package body **882**, sometimes called over molded. The removable carrier is removed thus exposing active surface **122** of silicon die fingerprint sensor **120** and lower surface **882**L of package body **882**. Traces **996** are formed, e.g., by selectively applying a conductive material such as copper. Protective coating **136** is then applied to cover traces **996**, lower surface **882**L of package body **882** and active surface **122** of silicon die fingerprint sensor **120**.

Via apertures **894** are formed through package body **882**, e.g., using laser ablation, to expose traces **996**. Via apertures **894** are filled with electrically conductive material, e.g., copper, to form vias **884**. Optionally, upper traces **888** are formed and interconnection balls **892** are formed on terminals **890**.

Although a particular order of operations is provided, the operations are performed in a different order in another embodiment. For example, vias **884** can be formed prior to formation of traces **996**.

Further, in another embodiment, fingerprint sensor package **900** is formed with electronic component **770** (see FIG. **7**), sometimes called an ASIC, instead of silicon die fingerprint sensor **120**, In accordance with this embodiment, RDL traces **996** form the sensing element, i.e., perform the function of sensing element **128**. Thus, RDL traces **996** form both the sensing element and the interconnect in accordance with this embodiment.

FIG. **10** is a cross-sectional view of a hybrid fingerprint sensor package **1000** in accordance with another embodiment. Hybrid fingerprint sensor package **1000** of FIG. **10** is similar to fingerprint sensor packages **100**, **800** of FIGS. **2**, **8**, respectively, and only the significant differences are discussed below.

In accordance with this embodiment, bond pads **130** of silicon die fingerprint sensor **120** are physically and electrically connected to electronic component terminals **876** of traces **874** by flip chip bumps **878**. Optionally, underfill **880** is applied between active surface **122** of silicon die fingerprint sensor **120** and upper surface **802**U of thin substrate **802** and to enclose flip chip bumps **878**.

Substrate **102**, sometimes called a second substrate, is mounted to thin substrate **802**, sometimes called a primary substrate. More particularly, substrate terminals **886** of traces **874** are electrically connected to vias **112** at lower surface **102**L of substrate **102** with conductive substrate bumps **1098**. In one embodiment, an adhesive **1099** fills the region between lower surface **102**L of substrate **102** and upper surface **802**U of thin substrate **802**.

Package body **132** is formed around silicon die fingerprint sensor **120** and fills fingerprint sensor cavity **104** and thus covers the portion of upper surface **802**U of thin substrate **802** exposed through fingerprint sensor cavity **104**.

FIG. **11** is a cross-sectional view of a fingerprint sensor package **1100** in accordance with another embodiment. Fingerprint sensor package **1100** of FIG. **11** is similar to fingerprint sensor package **700** of FIG. **7** and only the significant differences are discussed below.

Referring now to FIG. **11**, in accordance with this embodiment, fingerprint sensor package **1100** includes four primary layers, a layer L0 (layer 0), a layer L1 (layer 1), a layer L2 (layer 2), and layer L3 (layer 3). Layer L0 is sometimes called a blank. Layer L0 is a dielectric layer.

Layer L1 is mounted on layer L2, e.g., with adhesive. In one embodiment, layer L1 is sensing element on flex fingerprint sensor **720**. As discussed above, sensing element on flex fingerprint sensor **720** includes flexible substrate **762**, sensing element **728** and traces **763**. Flexible substrate **762** is a flexible dielectric substrate that is mounted to layer L0. Sensing element **728** is formed on flexible substrate **762**. Sensing element **728** senses fingerprints placed upon layer L0 directly opposite sensing element **728**.

Traces **763** are formed on flexible substrate **762**. Traces **763** include substrate terminals **764** and electronic component terminals **769**, e.g., thick tin plated bump pads. Electronic component **770** is flip chip mounted, i.e., bond pads **771** thereof, to electronic component terminals **769** with flip chip bumps **772**. Electronic component **770** is an application specific integrated circuit (ASIC) that controls the operation of sensing element **728** as those of skill in the art will understand in light of this disclosure.

Layer L2 includes a substrate **1102** having a lower, e.g., first, surface **1102**L and an upper, e.g., second, surface **1102**U. Substrate **1102** further includes a fingerprint sensor cavity **1104**A formed therein. Fingerprint sensor cavity **1104**A, sometimes called a hole or aperture, extends entirely through substrate **1102** and between upper surface **1102**U and lower surface **1102**L.

Fingerprint sensor cavity **1104**A is defined by a fingerprint sensor cavity sidewall **1106**A. Fingerprint sensor cavity sidewall **1106**A extends perpendicularly between upper surface **1102**U and lower surface **1102**L.

Substrate **1102** further includes outer sides **1102**S extending perpendicularly between upper surface **1102**U and lower surface **1102**L. Substrate **1102** includes a dielectric material such as laminate, ceramic, printed circuit board material, or other dielectric material.

Substrate **1102** further includes lower terminals **1118** at lower surface **1102**L and upper terminals **1114** at upper surface **1102**U. Lower terminals **1118** are electrically connected to upper terminals **1114** by electrically conductive vias **1112** extending through substrate **1102** between upper surface **1102**U and lower surface **1102**L. Substrate **1102** can further include traces that re-route the pattern of lower terminals **1118** to the pattern of upper terminals **1114**. Further, instead of straight though vias **1112**, in one embodiment, substrate **1102** is a multilayer substrate and a plurality of vias and/or internal traces form the electrical interconnection between lower terminals **1118** and upper terminals **1114**.

Lower terminals **1118** are electrically connected to substrate terminals **764** with conductive substrate bumps **766**, e.g., copper paste. In one embodiment, an adhesive **768** fills the region between lower surface **1102**L of substrate **1102** and sensing element on flex fingerprint sensor **720**.

Layer L3 provides routing and the package ball grid array. Layer L3 includes a substrate **1180** having a lower, e.g., first, surface **1180**L and an upper, e.g., second surface **1180**U. Substrate **1180** further includes a fingerprint sensor cavity **1104**B formed therein. Fingerprint sensor cavity **1104**B, sometimes called a hole or aperture, extends entirely through substrate **1180** and between upper surface **1180**U and lower surface **1180**L.

Fingerprint sensor cavity **1104**B is defined by a fingerprint sensor cavity sidewall **1106**B. Fingerprint sensor cavity sidewall **1106**B extends perpendicularly between upper surface **1180**U and lower surface **1180**L.

Fingerprint sensor cavities **1104**A, **1104**B of layers L2, L3 collectively form a fingerprint sensor cavity **1104**. Further, fingerprint sensor cavity sidewalls **1106**A, **1106**B collectively form a fingerprint sensor cavity sidewall **1106**.

Substrate **1180** further includes outer sides **1180**S extending perpendicularly between upper surface **1180**U and lower surface **1180**L. Substrate **1180** includes a dielectric material such as laminate, ceramic, printed circuit board material, or other dielectric material.

Substrate **1180** further includes terminals **1184**. Terminals **1184** are electrically connected to upper terminals **1114** of layer L2, e.g., by electrically conductive vias and/or traces of layer L3 and/or electrically conductive bumps. Interconnection balls **1116**, e.g., solder balls, are formed on terminals **1184**.

A package body **1132**, e.g., mold compound, is formed around electronic component **770** and the exposed portion of sensing element on flex fingerprint sensor **720**. More particularly, package body **1132** fills fingerprint sensor cavity **1104**.

In accordance with one embodiment, layers L1, L2, L3 further includes solder resists **1186**, **1188**, **1190**, sometimes called solder masks. Solder resist **1186**, **1188**, **1190** cover and protect electrically conductive structures, e.g., copper traces, of layers L1, L2 and L3 while exposing terminals.

In one embodiment, fingerprint sensor package **1100** is formed in a panel, e.g., a 74×240 mm panel, having 270 units per strip. Further, various layers L0, L1, L2, L3 can be pre-assembled. For example, layers L2, L3 can be pre-assembled.

FIG. **12** is a cross-sectional view of a fingerprint sensor package **1200** in accordance with yet another embodiment. Fingerprint sensor package **1200** of FIG. **12** is similar to fingerprint sensor package **1100** of FIG. **11** and only the significant differences are discussed below.

Referring now to FIG. **12**, fingerprint sensor package **1200** includes a dielectric silicon interposer **1202**. Formed on an upper, e.g., first, surface **1202**U of silicon interposer **1202** are electrically conductive traces **1274**.

Bond pads **130** of silicon die fingerprint sensor **120** are physically and electrically connected to electronic component terminals **1276**, e.g., comprising a tin-silver (Sn—Ag) finish, of traces **1274** by electrically conductive flip chip bumps **1278**, i.e., silicon die fingerprint sensor **120** is flip chip mounted to traces **1274**. Optionally, an underfill **1280** is applied between active surface **122** of silicon die fingerprint sensor **120** and upper surface **1202**U of silicon interposer **1202** and to enclose flip chip bumps **1278**.

To reduce the distance between a finger touching silicon interposer **1202** and sensing element **128**, in one embodiment, silicon interposer **1202** is thinned.

Lower terminals **1118** are electrically connected to substrate terminals **1286** of traces **1274** with conductive substrate bumps **766**, e.g., copper paste. In one embodiment, an adhesive **768** fills the region between lower surface **1102**L of substrate **1102** and upper surface **1202**U of silicon interposer **1202**.

Package body **1132** encloses inactive surface **124** and sides **126** of silicon die fingerprint sensor **120**, underfill **1280**, upper surface **1202**U of silicon interposer **1202**, and any expose portions of traces **1274**.

Although specific embodiments were described herein, the scope of the invention is not limited to those specific embodiments. Numerous variations, whether explicitly given in the specification or not, such as differences in structure, dimension, and use of material, are possible. The scope of the invention is at least as broad as given by the following claims.

What is claimed is:

1. An electronic component package comprising:

a fingerprint sensor comprising an active surface comprising a sensing element for directly sensing fingerprints; and

a substrate comprising a fingerprint sensor cavity, a first surface and a second surface, the first surface and the second surface corresponding respectively to a lower limit and an upper limit of a volume of the fingerprint sensor cavity, wherein the fingerprint sensor including the sensing element is located within the volume of the fingerprint sensor cavity and the active surface of the fingerprint sensor is parallel to and coplanar with the first surface of the substrate, wherein the substrate further comprises traces on the first surface coupled to bond pads on the active surface of the fingerprint sensor.

2. The electronic component package of claim **1** further comprising bond wires coupling the bond pads to the traces.

3. The electronic component package of claim **1** further comprising polymer thick film (PTF) conductors coupling the bond pads to the traces.

4. The electronic component package of claim **1** further comprising a protective coating covering the active surface, the traces, and the first surface of the substrate.

5. The electronic component package of claim **1** further comprising terminals on a second surface of the substrate, the terminals being coupled to the traces.

6. The electronic component package of claim **1** wherein the electronic component package is selected from the group consisting of a Ball Grid Array (BGA) and a Land Grid Array (LGA).

7. The electronic component package of claim **1** further comprising a package body in the fingerprint sensor cavity.

8. The electronic component package of claim **7** wherein the package body mounts the fingerprint sensor in the fingerprint sensor cavity.

9. The electronic component package of claim **7** wherein the package body comprises a surface parallel to and coplanar with the active surface of the fingerprint sensor and the first surface of the substrate.

10. The electronic component package of claim **1** further comprising a bezel adjacent the fingerprint sensor.

11. The electronic component package of claim **10** wherein the bezel comprises a conductive ink coupled to the first surface of the substrate.

12. The electronic component package of claim **1** further comprising a diode having a light emitting face parallel to and coplanar with the first surface of the substrate.

13. An electronic component package comprising:

a primary substrate comprising a first surface comprising traces thereon;

a fingerprint sensor mounted to terminals of the traces;

a package body directly contacting and enclosing an inactive surface and sides of the fingerprint sensor; and

electrically conductive vias extending entirely through the package body between a first surface of the package body and a second surface of the package body, the vias being coupled to the traces.

14. The electronic component package of claim **13** further comprising a second substrate comprising a fingerprint sensor cavity in which the fingerprint sensor is located.

15. An electronic component package comprising:

a flexible substrate;

a fingerprint sensing element coupled to the flexible substrate;

traces coupled to the flexible substrate, the traces comprising electronic component terminals;

an electronic component coupled to the electronic component terminals;

a substrate comprising a fingerprint sensor cavity in which the electronic component is located; and

a package body in the fingerprint sensor cavity and directly contacting and enclosing the electronic component.

16. The electronic component package of claim **15** further comprising a sensing element on flex fingerprint sensor comprising the flexible substrate, the fingerprint sensing element, and the traces.

17. The electronic component package of claim **15** further comprising an adhesive between the flexible substrate and the substrate.

18. An electronic component package comprising:

an electronic component comprising an active surface comprising bond pads;

redistribution layer (RDL) traces coupled to the bond pads;

a package body directly contacting and encapsulating an inactive surface opposite the active surface and sides of the electronic component; and

electrically conductive vias in the package body, wherein the RDL traces form an interconnect between the bond pads and the vias and also form a fingerprint sensing element.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,717,775 B1
APPLICATION NO. : 12/848833
DATED : May 6, 2014
INVENTOR(S) : Bolognia et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 435 days.

Signed and Sealed this
Eighteenth Day of August, 2015

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office